Agenda for Today's Webinar

- Welcome and Logistics
- Technology Overview
- Licensing Opportunities
- Q & A

Presenters

Laura Fobel

Technology Transfer Officer,
NASA Armstrong TTO

Mark Skoog

Principal Investigator,
Automatic Systems Project Office

Armstrong Flight Research Center

Advancing technology & science through flight

- Multi-disciplinary flight research
- Cutting-edge range & aircraft test facilities
- Flight systems & test technique development
- Diverse fleet of experimental & test aircraft
  - Piloted and unpiloted
- Airborne remote sensing & science observation

Armstrong Technology Transfer Office

Manages commercialization of innovations

Facilitates research collaborations (e.g., Space Act Agreements)

Supports utilization of SBIR and STTR results for NASA mission use and commercialization

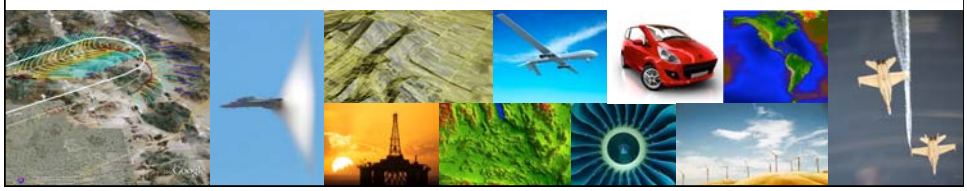
Armstrong's Technology Portfolio

Sample Innovations

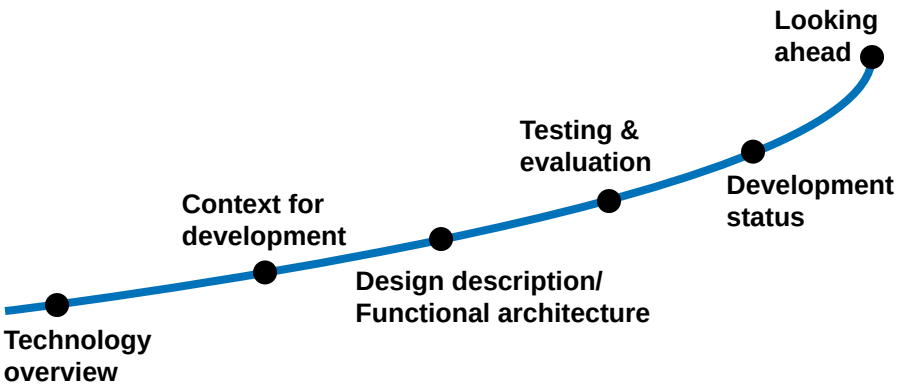
- Control systems
- Sensors
- Software packages

Real-World Impacts

- Improve flight and pilot safety
- Help fight forest fires
- Enhance security monitoring



Improved Ground Collision Avoidance



Technology Overview

Technologies Available for Licensing

NASA ID	Official Title	Notes
Collision Avoidance System		
DRC-012-033	Improved Automatic Aircraft Collision Avoidance System and Method	• Algorithms for improved collision avoidance • Patent-pending
Digital Terrain Data Handling		
DRC-009-008	Improved Ground Collision Avoidance System	• Method to encode/decode data • Patent-pending
DRC-012-001	Global Elevation Data Adaptive Compression System (GEDACS)	• Software to implement DRC-009-008

Preventing Controlled Flight into Terrain (CFIT)

System includes:

- High-fidelity terrain mapping
- Enhanced vehicle performance modeling
- Multi-directional avoidance techniques
- Efficient data handling
- User-friendly warnings
- Flexible platform
  - Variety of aircraft
  - Avionics system, mobile app–based, electronic flight bag (EFB)

Applications

Technology Overview

Context for Development

Video: http://www.nasa.gov/offices/ipp/centers/dfrc/technology/DRC-012-033-collision-avoidance.html

Reasons Collision Avoidance Improvements Are Needed

1. Controlled flight into terrain or midair collisions

Military

#1 cause fatalities
#2 cause mishaps

General Aviation

#2 cause fatalities

Reasons Collision Avoidance Improvements Are Needed

2. Existing solutions unsuccessful or impractical

Military

- Ineffective warning systems for fighter pilots
- Training achievements maxed out

General Aviation

- Equipage to prevent can be cost prohibitive

NASA Armstrong's History in Collision Avoidance

1980	2000	2010	2015
Semi-Automatic	Semi-Automatic	Fully Automatic	Manual
			
Research F-16	*Production F-16*	*Research UAV*	*GA Aircraft (SR22)*
Advanced Fighter Technology Integration	**Automated Collision Avoidance Technology**	**Small Unmanned Air Vehicle**	**Improved Collision Avoidance System**

Automatic vs. Pilot Flown Warning Ground Collision Avoidance

Top-Level System Description:
- Uses nav solution and digital terrain
- Algorithm determines when and where to avoid

Algorithm Features:
- Nuisance free
- Platform agnostic
- Sensor agnostic
- Modular software architecture

Automatic

Engages high-authority autopilot to perform maneuver

Takes Control from Pilot
- Warning cues are optional

F-16
2010 Risk Reduction Project
2013-14 Production Fielding

Small UAV
2012 Migration to Smart-Phone

Pilot-Flown Warning

Issues Warning Cue
- Tells pilot when and where to avoid

SR22
2013-14 Evaluation

Technology Overview

Design Description and Functional Architecture

Guiding Principles

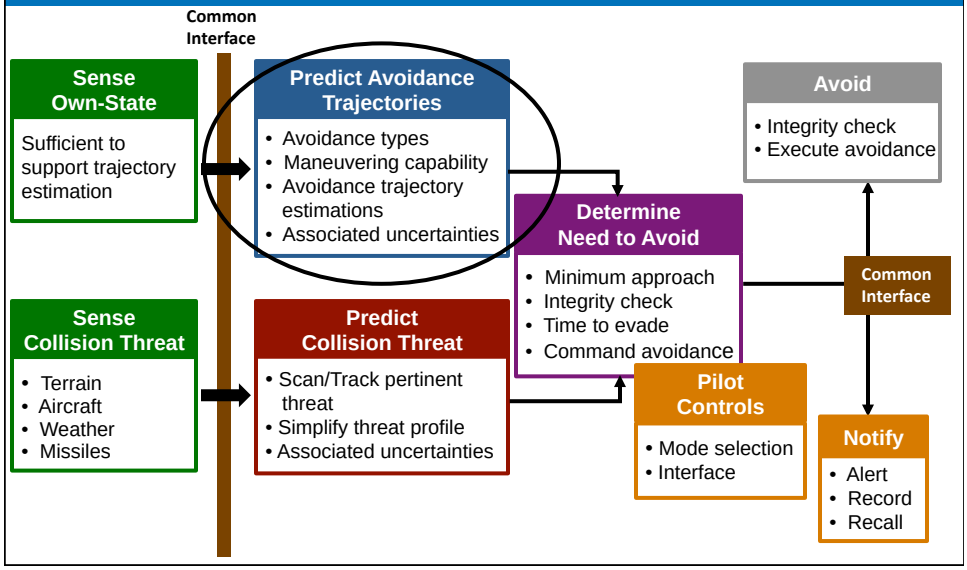
Requirements

- Do no harm
- Do not impede
- Avoid collision

Approach

- Codified
- Modularly partitioned at the functional level

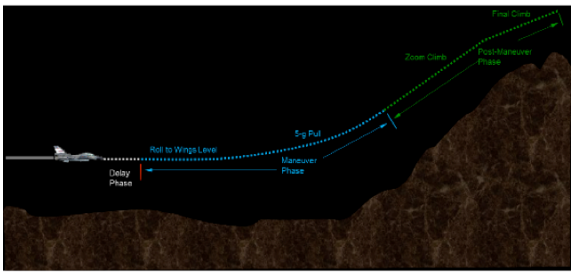
Collision Avoidance Common Functional Architecture



System Predicts Avoidance Trajectories

Faster than real-time simulation

Predicts avoidance trajectory through space



Kinematic model
- Delay phase
- Onset phase
- Steady-state phase

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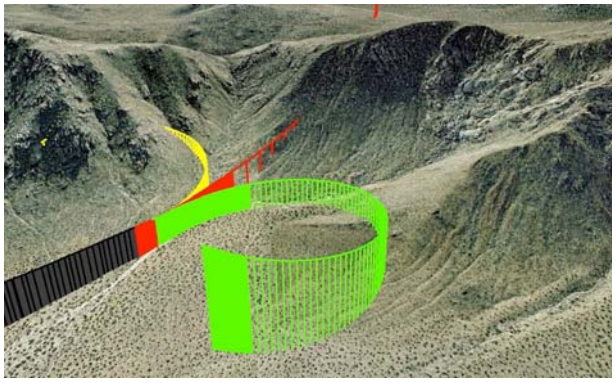
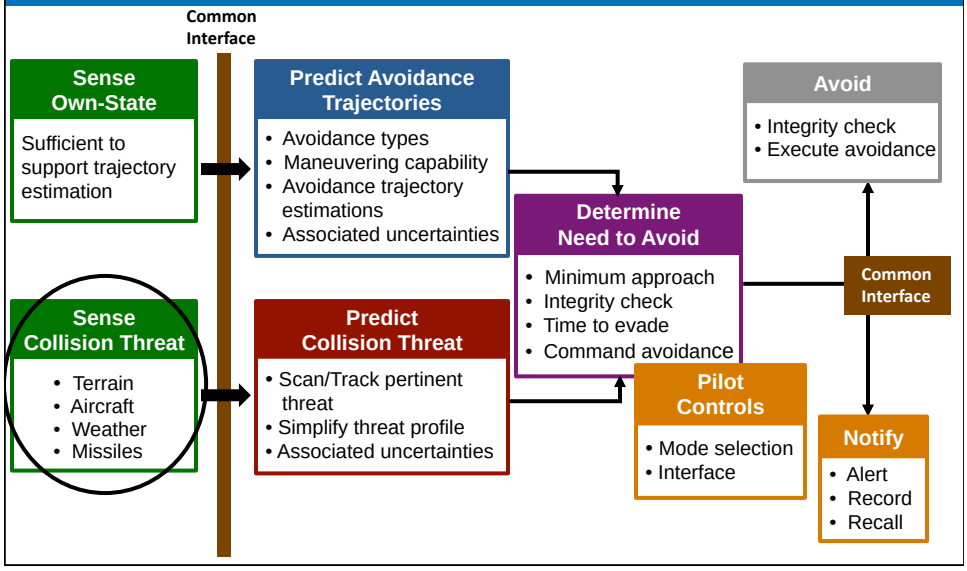


System Predicts Avoidance Trajectories

	F-16 System	Small UAV System	GA System (SR22)
			
Trajectory	**Single Trajectory** • Roll to wings-level • Pull 5-6g or 18°–20° angle-of-attack • Over 30,000 f/m climb rate	**Multi-Trajectory** • Wings-level • 40° left and right bank • 1,000 f/m climb rate	**Multi-Trajectory** • 0 and ±30° bank • Vy+10 climb rate • Modified chandelle
Attitude	**All Attitude** • Bank • Dive	**Limited Attitude** • ±60° bank • 45° dive • Does not support nadir	**Limited Attitude** • ±60° bank • 45° dive • Does not support nadir
Envelope	**Near-All Envelope** • > 2g available • Mach 2+ • All store loadings	**All Envelope** • 40 to 80 knots • < 1,500 feet above ground	**All Envelope** • Above stall to Vmax • All altitudes • All gross weights

Collision Avoidance Common Functional Architecture



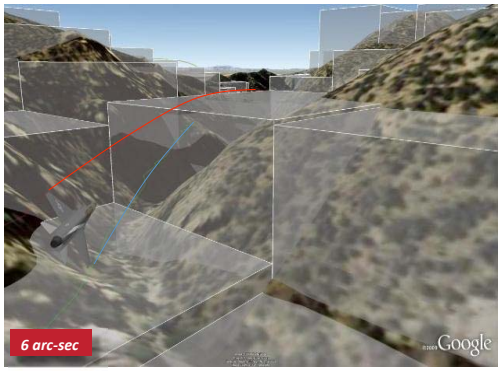
System Senses Collision Threat

Digital terrain map (DTM)

- Array of terrain elevations
- Oriented to latitude & longitude

Provided by third party

- Civil: U.S. Geological Survey
- Military: National Geospatial Intelligence Agency
- Supporting wide customer base



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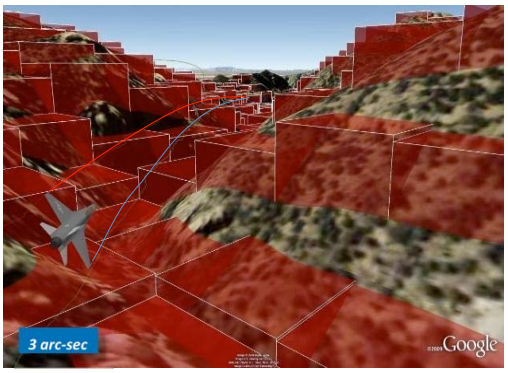

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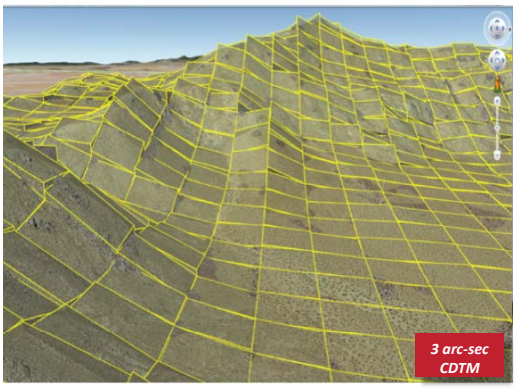
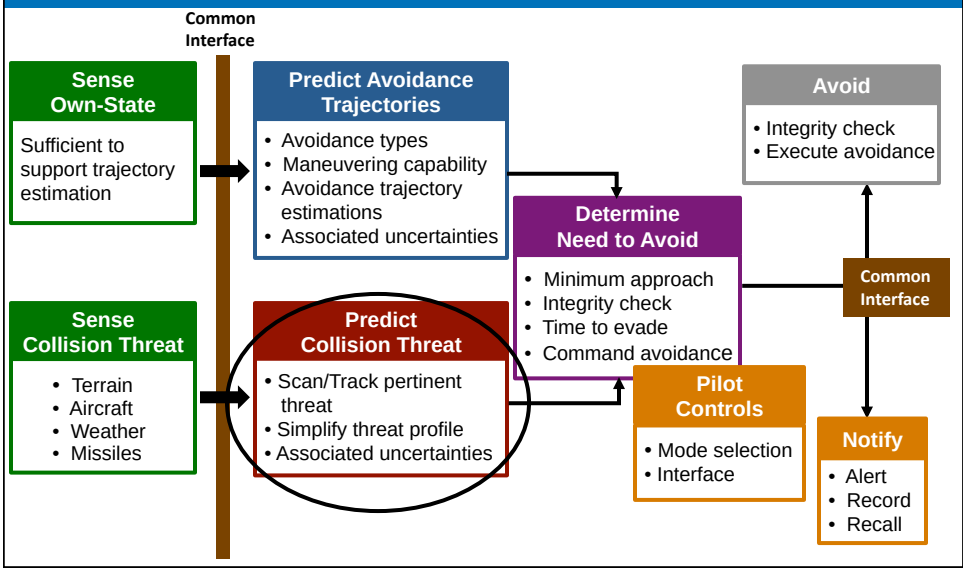


System Senses Collision Threat

	F-16 System	Small UAV & GA (SR22) Systems
		 
Digital Terrain Map	**Digital Terrain Elevation Data (DTED)** • Regular array • Even spacing	**Compressed Digital Terrain Map (CDTM)** • Semi-regular array • Size and fidelity adjustable to user requirements
Map Size	• ~70 meg • ~5°x5° lat/long — ~90k sq. mi.	• ~180 meg • 80°N to 80°S — ~194M sq. mi.

Collision Avoidance Common Functional Architecture

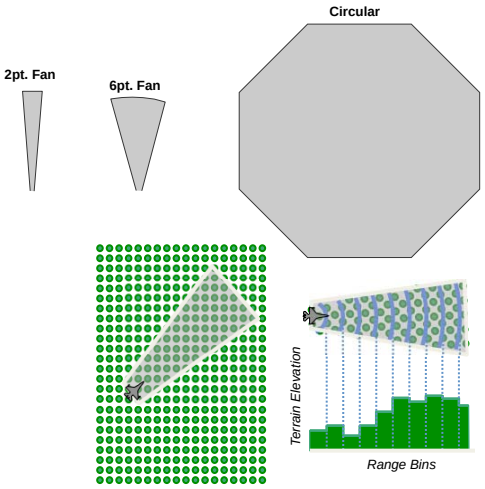


System Predicts Collision Threat

Terrain processing (scanning)

Subsample terrain data
- Terrain near aircraft

Simplify to 2-dimensional profile
- Preparation to compare to avoidance trajectory



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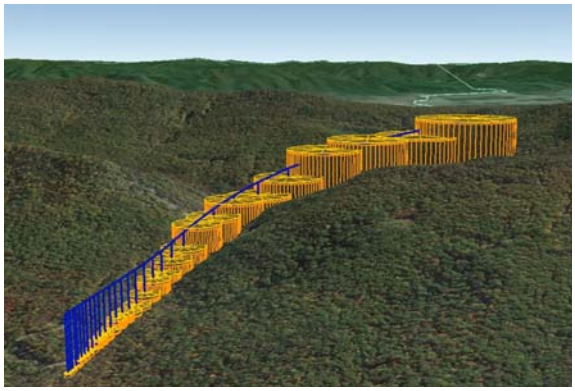
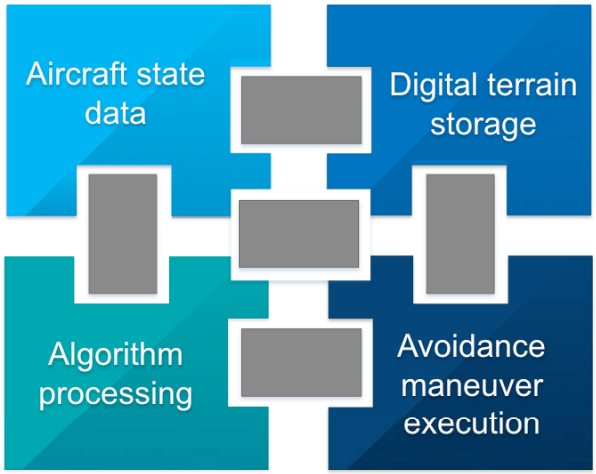


System Predicts Collision Threat

	F-16 System	Small UAV & GA (SR22) Systems
		 
Sub-Sample Approach	• Various geometric shapes • Dependent on aircraft state	• Trajectory-based – Ground track – Track uncertainty • Aircraft agnostic
2-Dimensional Profile	• ~Regularly spaced bins	• Semi-regular spaced bins – Track uncertainty

Integration and Installation

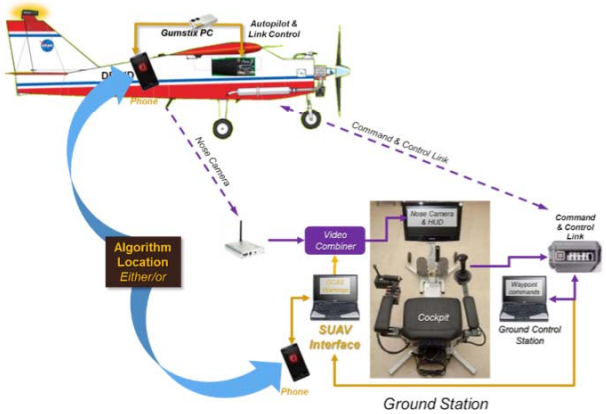
Pulling together system components



Integration Is Flexible

	Semi-automatic	*Fully automatic*	*Manual*
	F-16 System	**Small UAV System**	**GA System (SR22)**
			
Aircraft State Data	• 1553 mux	• RS-232 to USB • Command-and-control link	• USB or wireless from research computer
Digital Terrain Storage	• Advanced data transfer cartridge	• Micro-SD card	• Micro-SD card
Algorithm Processing	• Advanced data transfer unit	• Android smart phone	• Android smart phone
Avoidance Maneuver Execution	• High-authority autopilot in FCS • No auto-throttle	• Piccolo II autopilot	• Pilot flown

Integration Is Continuing to Evolve



Technology Overview

Testing and Evaluation

Testing: F-16

Collision Avoidance

Excellent prevention
- All historical F-16 CFIT mishaps covered

Nuisance-Free Flight Performance

- **High, low, and strafe (attacking):** Supports required missions
- **Air show:** Supports low-altitude split-S execution

Do No Harm

Works as designed

Testing: Small UAV

Collision Avoidance

Excellent protection

- Better than anticipated in winds/gusts
- Outperforms ability of ground observers

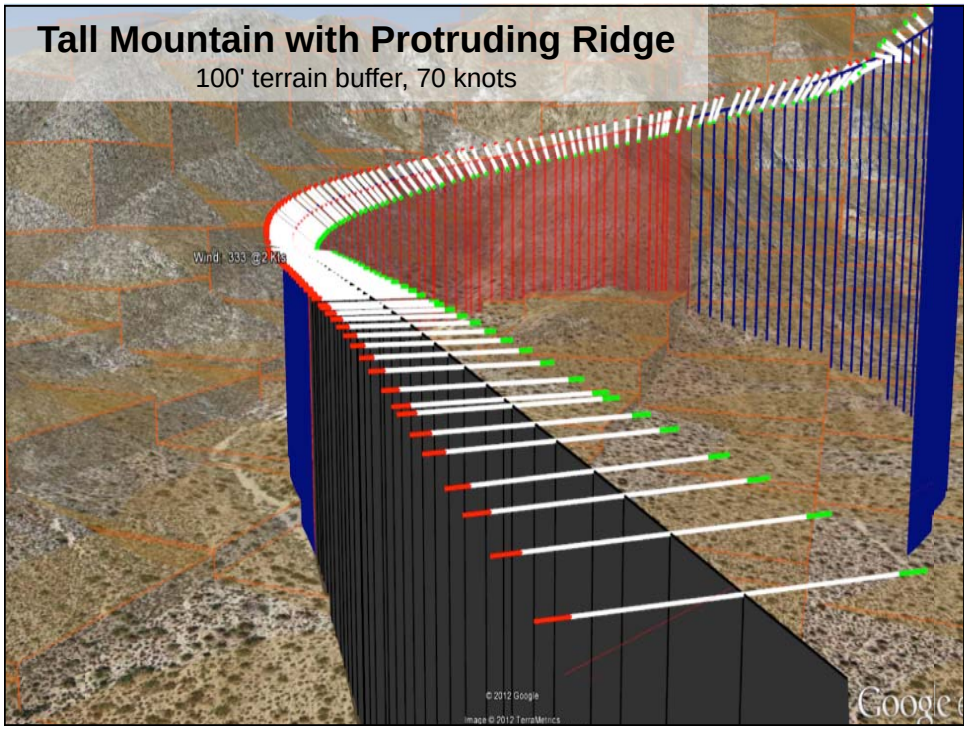
Nuisance-Free Potential

- Multi-trajectory mandatory for lower performing aircraft

Integrity Management

Improvements needed

- Phone-on-ground configuration requires more complex integrity monitoring



Testing: SR22

Integration Results

- 40 hours to modify algorithm to SR22
- 10 working days to integrate system

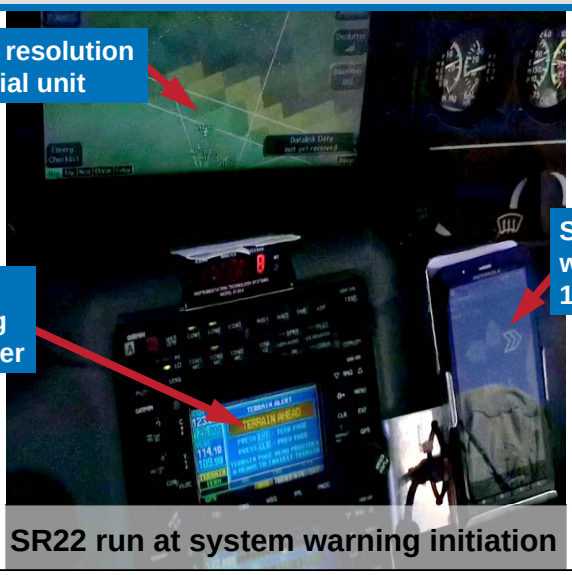
Results of 5 Flight Tests

- Characterization
- Collision avoidance
- Excellent mishap prevention
- Nuisance-free operations

Looking Ahead

- Better cuing required
- Appropriate pilot reaction time may be an issue

Do Not Impede



SR22 run at system warning initiation

Technology Overview

Development Status

Current Status: What It Does Now

High-accuracy aircraft maneuver model

Advanced terrain handling

Multi-trajectory avoidance

Android OS/Nexus 4

Experimental wireless interface

Current Status: Recent Improvements

Summer 2014

- Pilot-vehicle interface
  - Warning displays
  - Preference settings
- Conventional wireless interface
- Easy aircraft adaptation for EFBs

Demonstration: Fall 2014

Future Goals and Implementations

Goals

- Accurate collision avoidance for all aircraft
- Automatic and manual versions

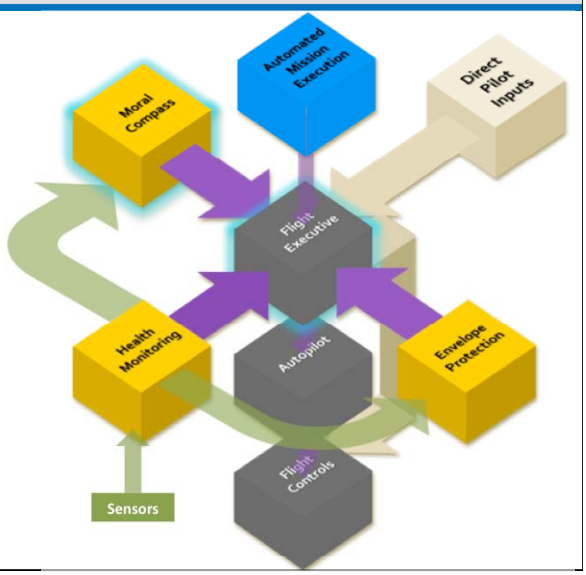
Possible Formats

- Fully automated ground collision avoidance
- Glass cockpit warning system
- Electronic flight bag (EFB) or phone warning system with wireless sensor inputs
- Stand-alone version using smart-device sensors

Roadmap – Vehicle Autonomy

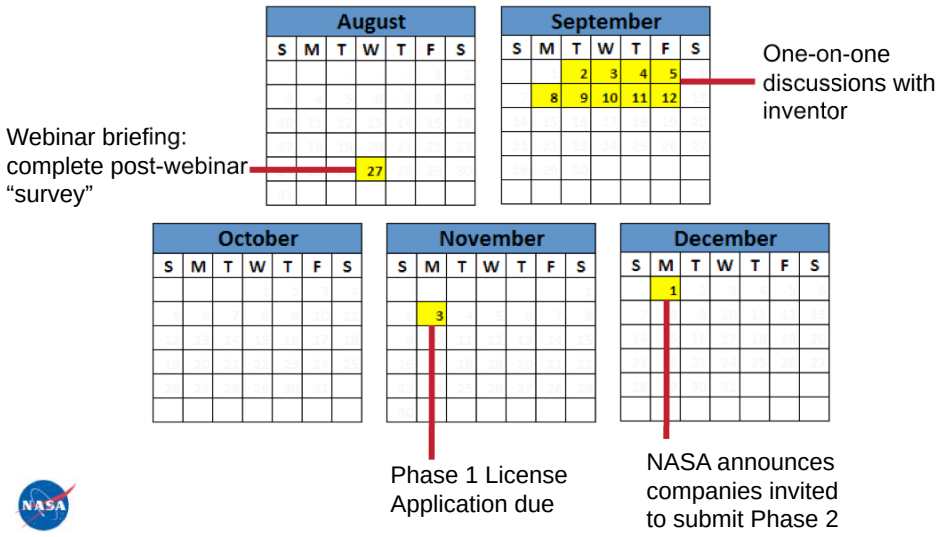
Ground collision avoidance is the first in a series of planned autonomy systems

This comprehensive web will enable vehicle autonomy as provide warning systems



Licensing Opportunities

Armstrong Licensing Agreement Process

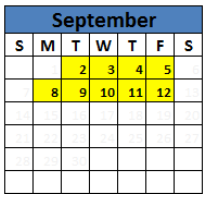


Armstrong Licensing Agreement Process

Follow-on steps:

- Phase 2 License Application (by invitation)
- Phase 3 commercialization plan discussions
- NASA drafts license agreement
- Negotiate license language
- Execute license

One-on-One Discussions



Opportunity for each company to speak directly with the inventor for 30 minutes

- Ask questions
- Discuss company-specific information

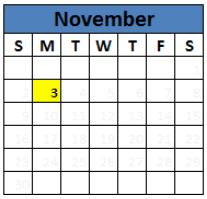
Covered by Uniform Trade Secrets Act

- Not be shared publicly
- Not shared with other companies

Non-confidential discussion
(no NDAs signed)

Request a meeting at http://www.meetme.so/DanielleMcCulloch

Phase 1 License Application



Enables evaluation of benefits for NASA, taxpayers, and the company

All offers will be evaluated at the same time

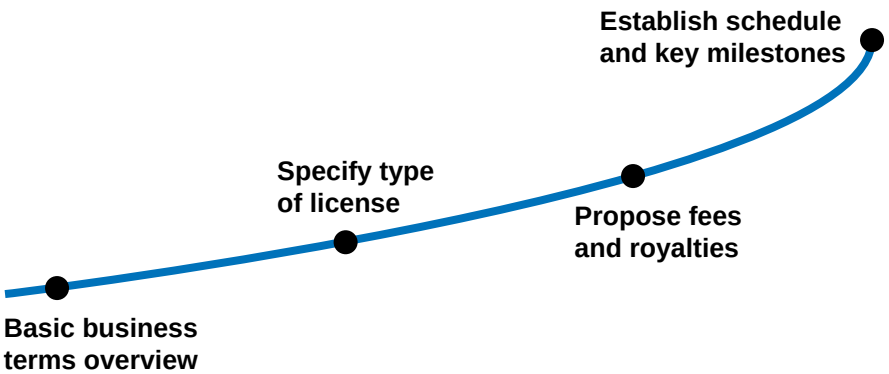
- Maximize benefits through simultaneous, strategic selection
- Not all applicants can be accepted due to limited inventor availability

Download Phase 1: Application for License to Practice Invention:
http://www.nasa.gov/offices/ipp/centers/dfrc/technology/
DRC-012-033-collision-avoidance.html

Phase 1 Components

- Company background
- Product or service that will use NASA technology
- Market size
- Initial offer
- Capabilities
  - Technical, management, marketing, and financial
- Desired support from NASA
- Appendix
  - *Pro forma* income statement – form provided

Initial Offer



Basic Business Terms

Which NASA invention(s):

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Collision Avoidance System		
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Digital Terrain Data Handling		
DRC-009-008	Improved Ground Collision Avoidance System	• Method to encode/decode data • Patent-pending
DRC-012-001	Global Elevation Data Adaptive Compression System (GEDACS)	• Software to implement DRC-009-008

Basic Business Terms

Which NASA invention(s)

Fields of use, period of time, or geographic area

- Limit to areas where licensee intends to market

Highlight any significant terms or conditions

Type of License

Exclusive or Partially Exclusive

- Must be substantially manufactured in the U.S. for products sold in U.S.
- Sub-licensing allowed
- Patent cost reimbursement

Non-Exclusive

- No sub-licensing
- U.S. manufacturing not required
- Pro-rated patent cost reimbursement
- Multiple licensees

Fees

Fees

Upfront fee

Patenting costs

Royalties

Running Royalty

Paid at least annually
- Based on Net Sales*
- Specify preferred metric (e.g., units)
- Ascending/Descending royalty structure

Minimum annual royalties

Non-royalty sublicensing payments
– For exclusive license

***Net Sales (as defined in license) = gross sales – (returns + discounts + shipping/insurance + taxes/duties)**

Schedule and Key Milestones

Annual reports

Milestone examples

- ✓ Prototype demonstration
- ✓ Manufacturing process development
- ✓ Funding/Investments (especially for startups)
- ✓ Marketing of product
- ✓ Achievement of sales

Phase 1 Components

- Company background
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  - Technical, management, marketing, and financial
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- Appendix
  - *Pro forma* income statement – form provided

Pro Forma Income Statement

- Years until positive cash flow ***plus*** 2 more years
- Only for the product line using NASA's technology
- Include proposed royalty payments and minimums
- Ensure assumptions are clear

Download *pro forma* template:
http://www.nasa.gov/offices/ipp/centers/dfrc/technology/DRC-012-033-collision-avoidance.html

Sample *Pro Forma* Income Statement

Instructions: Please use this Pro Forma template in support of Part 1 of the license application.
Complete only the green shaded boxes. All other values will be calculated from your inputs.

Product:	ABC		
Percentage of Product Attributable to Licensed Technology:	80.0%		
Discount / Risk Rate	7.0%		
Company Financials	**Year 1**	**Year 2**	**Year 3**
Revenue			
Price per Unit	$5,000	$5,000	$5,000
Units Sold	600	720	864
Projected Sales	$3,000,000	$3,600,000	$4,320,000
Expenses			
Cost of Goods Sold	$1,500,000	$1,800,000	$2,160,000
Selling, General & Admin. Expenses	$750,000	$900,000	$1,080,000
R&D Costs	$200,000	$200,000	$150,000
Total Expense	$2,450,000	$2,900,000	$3,390,000
Pre-Licensing Fee Margins			
Net Profit	$550,000	$700,000	$930,000
Gross Margin (%)	18.3%	19.4%	21.5%
Licensing Fees			
Up Front Licensing Fee	$200,000		
Royalty Rate	7.00%	7.07%	7.14%
Royalty Payment	$210,000	$254,520	$308,478
Minimum Annual Royalty Payment	$100,000	$200,000	$300,000
Actual Royalty	$410,000	$254,520	$308,478
Cumulative NPV of Royalty Revenue	$410,000	$605,485	$857,295

Current values are for example only. Please provide accurate and appropriate estimates for your company and product offering.

Royalty Rate Structure	Annual rate inc. or dec.
Starting Royalty Rate	7.0%
Annual Change in Royalty Rate (Increase or Decrease)	1.0%

Repeat sections for each varied product types

Sum all revenues – Sum all expenses

Evaluation Criteria

Four types of factors:

Not all qualified companies will be granted a license. Submit your best offer.

Negotiations

Finding the win-win

Negotiable Items

- Type of license
- Field of use
- Upfront licensing fee
- Running royalty rate
- Yearly minimums
- Milestones

Negotiations

Finding the win-win

Non-Negotiable Items

- NASA/U.S. government retains irrevocable, royalty-free rights to technology for noncommercial uses
- March-in rights
- Indemnity and warranty

Signature and Monitoring

Agreement(s) Signed

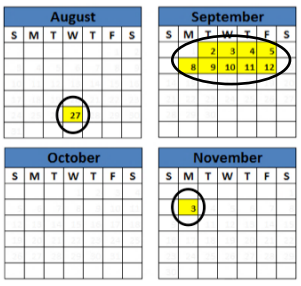
- All applicants will be notified after signing

NASA Monitoring of Commercialization

- Ensure milestones met
- Ensure compliance with annual reporting and payments
- Successes: We will collaborate with you to celebrate/publicize

Next Steps

1. Complete post-webinar "survey"
   Appears as you sign out today



2. Schedule one-on-one
   Inventor available September 2–12
   http://www.meetme.so/DanielleMcCulloch

3. Download Phase 1 License Application
   http://www.nasa.gov/offices/ipp/centers/dfrc/technology/DRC-012-033-collision-avoidance.html

4. Submit Phase 1 License Application and *pro forma*
   Due November 3

Questions

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661.276.5743